



BASIS OF ELECTROMAGNETIC COMPATIBILITY OF INTEGRATED CIRCUIT

Chapter III - BASIC CONCEPTS

Corrections of exercises

I. EXERCISE NO 1 - Unit conversion

Using the unit converter of IC-EMC, convert 0 dBm injected in a 50 Ω load resistance into dBμV.

Corrections:

A power of 0 dBm corresponds to 10^{-3} W. Using $P=V^2/R$, we deduce $V=0.22$ V, that is 107 dBμV.

$$V = \sqrt{PR} = \sqrt{10^{-3} \cdot 50} = 0.22 \text{ V} = 107 \text{ dB}\mu\text{V}$$

This result can be verified with the Unit converter tool of IC-EMC (Tools / dB/Linear unit converter):

6. The conversion result is obtained here

5. Click on 'dB to linear'

1. Type '0'

3. Select 'Watt'

4. Type '50'

2. Select 'dBm'

II. EXERCISE NO 2 - Unit conversion

A mobile phone receives a power of around -90 dBm. How much voltage does it represents on a 50 Ω input load? On a 1 MΩ input load? Knowing that typical gain of low-noise amplifiers is 20 dB, how many amplifier stages would be needed to obtain a 100 mV peak-to-peak signal?



Corrections

A -90 dBm power corresponds to 10^{-12} W that is 1 pW. The voltage across a 50 Ω input load is given by:

$$V = \sqrt{PR} = \sqrt{10^{-12} \cdot 50} = 7\mu V$$

To get 100 mV, a 83-dB amplification (x14000) is required, which is equivalent to 4 LNA stages.

$$V = \sqrt{PR} = \sqrt{10^{-12} \cdot 10^6} = 1mV$$

The voltage across a 1 MΩ input load is given by:

$$V = \sqrt{PR} = \sqrt{10^{-12} \cdot 10^6} = 1mV$$

To get 100 mV, a 40-dB amplification (x10000) is required, which is equivalent to 2 LNA stages.

III. EXERCISE NO 3- FFT Window

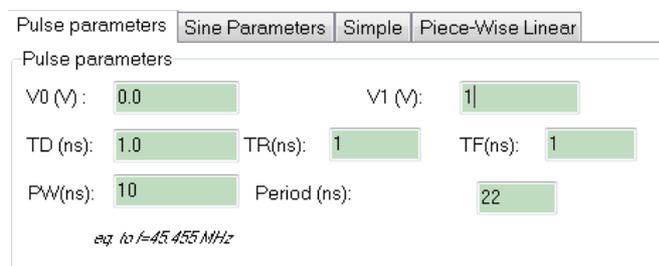
Investigate the role of the “Window” on the frequency spectrum of simple signals.

Corrections

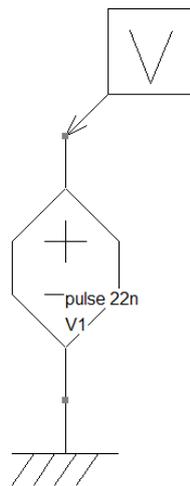
The Blackman and Hamming windows contributes to the reduction of the numerical noise due to the truncation of the signal in time domain. The Rectangular window increases significantly the numerical noise, while the peak energy remains similar in frequency and amplitude. However, the rectangular window ensures the best frequency resolution.

In order to illustrate it, let consider the FFT of a rectangular pulse signal with the following properties:

- Amplitude = 0 - 1 V
- Period = 22 ns
- Pulse width = 10 ns
- Rise/Fall time = 2 ns

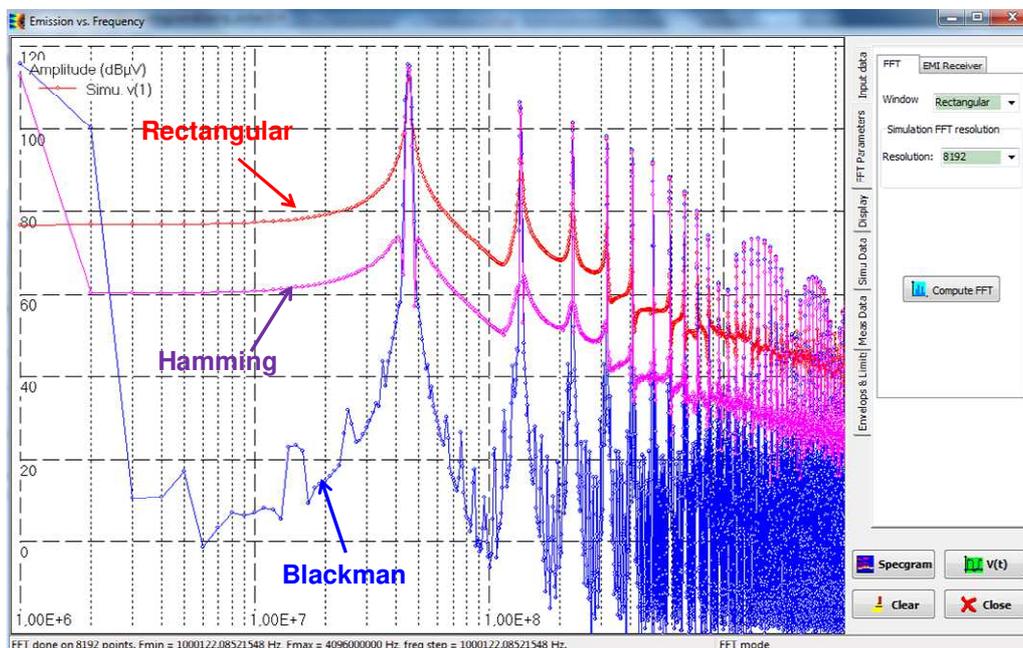


The schematic diagram is shown below and is given in the file windowing_pulse.sch. The transient simulation duration is 1 μs. The period of the signal has been chosen such that the number of simulated period is not integer. It increases the numerical noise.

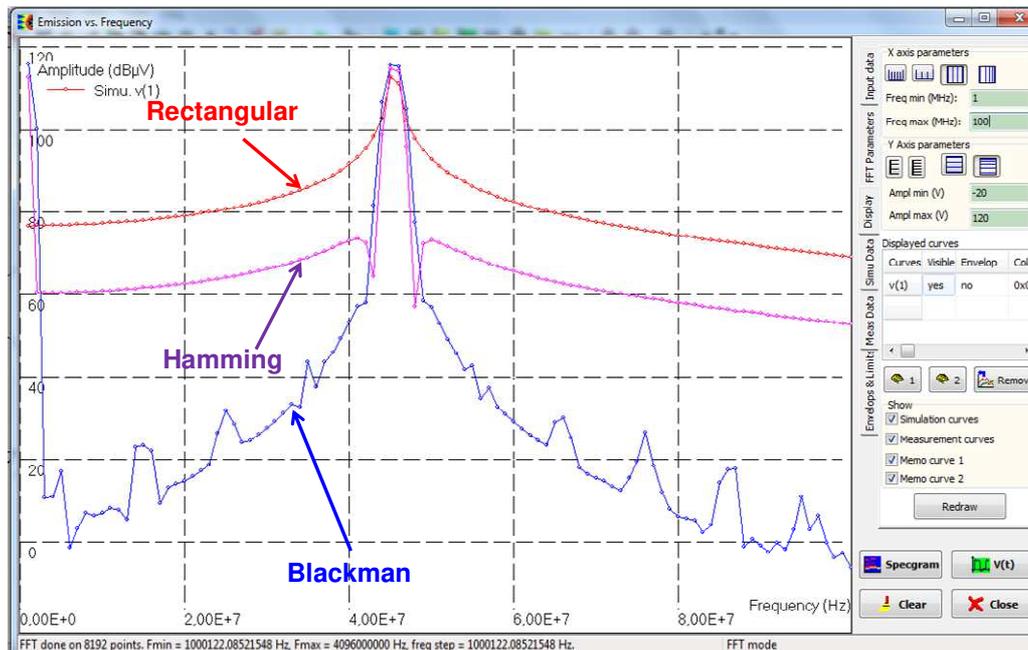


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■ 27/03/2017 18:54:42
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■ Book Basis of EMC of IC - Chap 3 - Exo 3
■ Analyse the effect of FFT windowing on the spectrum of a rectangular pulse signal

Click on to generate the netlist and launch the simulation. Click on to compute the spectrum of the simulated signal. You can change the window type in the part "FFT Parameters". The following figure compares the the spectrum of the signal with the three windows proposed by IC-EMC: rectangular, Hamming and Blackman. To plot these three curves, it is necessary to store both of them with the buttons 1 and 2.. The result confirms that Blackman and Hamming windows reduce the numerical noise, contrary to rectangular window. In this configuration, Blackman has better performances than Hamming in term of numerical noise reduction. The three filters give nearly the same results for the peak levels.



Let have a look at the fundamental frequency (45 MHz). Change the frequency axis settings to linear mode and zoom on the fundamental frequency. The result is shown below. If we compare the resolution of these three filters (i.e. the width of the peak associated to the fundamental frequency), it is clear that the rectangular window has the best resolution while the Blackman has the worst resolution.



IV. EXERCISE NO 4 - FFT points

What is the effect of “FFT resolution” on the frequency spectrum of the signal?

Corrections

Applying the FFT on a lower number of points decreases its precision. Increasing the number of points forces the software to add zero values to non-existing points, leading to a modification of the whole spectrum.

V. EXERCISE NO 5- Capacitance

Considering 2 metallic plates in a 10x10 cm PCB, separated by a 300μm thick FR4 oxide, what is the plane capacitance?

Corrections

Using the plate capacitance formulation $C = \epsilon_0 \epsilon_r S/d$, we obtain $8,85 \cdot 10^{-12} \times 3,9 \times 10^{-2} \times 10^{-2} / 0,3 \times 10^{-3} \approx 1,15 \text{ nF}$ (11 pF/cm²).

VI. EXERCISE NO 6- Inductance

What is the approximate inductance value of a 2x2-cm QFP package lead?

**Corrections**

Assuming the die is 1/3 of the package size (7x7mm), the maximum lead length at the corners of the QFP package is around 10 mm, equivalent to 10 nH in the worst case.

VII. EXERCISE NO 7- Near Field

At 10 mm distance, what is the magnetic field amplitude generated by a 10-mA, 1-GHz current flowing in a 10-mm package lead?

Corrections

Applying Eq. 3-31, with $h=10$ mm, $r=10$ mm, $I_0=10$ mA, the maximum magnetic field would be $1/4\pi = 0.08$ A/m.

$$\vec{H}_\phi \approx \frac{I_0 h}{4\pi r^2} \sin \theta \cdot e^{-j\beta r}$$